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DETERMINATION OF

MANPOWER REQUIREMENTS

FOR SCIENTISTS AND ENGINEERS

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

in Partial Fulfillment of the

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Master of Science

by

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Graduate Systems Management

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Preface

The shortage of scientists and engineers is a problem that has been discussed and debated for many years. As a graduate mechanical engineer, studying to leave the engineering discipline and enter that of management, the author is personally involved, albeit in a small way, in prolonging this "shortage." But as a manager, the author may have the responsibility of establishing manpower requirements for scientists and engineers. It was, therefore, personally significant that the author investigate this particular field. From this research effort the author gained a deep appreciation for the importance, as well as the difficulty, of fulfilling this responsibility well. From this paper it is hoped that the reader will receive a similar appreciation.

The success of this study was directly dependent on the willingness of more than fifty interviewees to discuss various aspects of this subject with the author. The author appreciates the time and ideas of these people. Whereas individual acknowledgement cannot be made to each of these interviewees, those that are specifically given credit in the body of this report are listed in the bibliography. Likewise, appreciation is expressed to the forty-six respondents who replied to the author's letter requesting information concerning their establishment of requirements for scientists and engineers. These are specifically indicated in Appendix B.

In June 1969 Captain Gabriel R. Faimon of the Department of Systems Management, Air Force Institute of Technology worked on the research effort with the author and contributed significantly to the formulation of the research objective and approach. Thanks is also due to

Lieutenant Colonel Robert H. McIntire and Lieutenant Colonel Frank A. Stickney, thesis advisors, both of the Department of Systems Management, for their invaluable suggestions and criticisms in the preparation of this thesis.

Although the author has done his best to insure the accuracy of names, dates, and organizations of interviewees and letter respondents as well as the accuracy of their quotations and ideas, he alone is responsible for any errors that appear in this paper.

William A. Brummer

Contents

Abstract

The establishment of operational manpower requirements for scientists and engineers is an important function of management. The objective of this research was first to describe and then to analyze this function for improvement. To describe the present procedure, the literature was reviewed; information was requested from 93 industrial firms, professional societies, and governmental agencies; and more than fifty persons were interviewed by the author. It was found that there is no definite, explicit method of deciding that a scientist or engineer is needed to perform a particular task. Rather, this function of management is greatly dependent on the individual manager's judgment and intuition.

When this procedure was analyzed, it was found that there are some specific determinants which are used to establish these requirements but, in general, managers are only vaguely aware of their significance. TASK RELATED DETERMINANTS are those which are related directly to the requirements of the task and include technical expertise, creativity, analytic ability, ability to communicate technical ideas, and the "ability to think" normally thought to be characteristic of a college graduate. NON-TASK RELATED DETERMINANTS are independent of the task and include flexibility of the scientist-engineer, economics, availability of personnel, "red tape", politics, prestige, prejudice, and program priority.

To improve this procedure of establishing requirements for scientists and engineers, it is proposed that managers should be taught to carefully and objectively identify <u>all</u> the specific determinants involved in a particular situation. Then they should judge the legitimacy of

each specific determinant on the basis of the organization's overall objectives and use only those determinants judged to be legitimate in the establishment of manpower requirements. The recommendations emphasize that top management must be sincerely interested in this type of improvement and assure that all management levels are working consistently toward this goal.

DETERMINATION OF MANPOWER REQUIREMENTS FOR SCIENTISTS AND ENGINEERS

I. Introduction

Statement of the Problem

This thesis is concerned with the problem of determining manpower requirements for scientific and engineering services. It is a description and analysis of the methods presently used to establish the requirements.

Scientific and engineering talent is a relatively scarce commodity, especially in the Air Force as will be shown later. It is, therefore, important that the available talent is not wasted. It is the function of a manager to direct and control his resources to accomplish the mission. While all but the poorest managers may eventually get the mission accomplished, the better managers will do it efficiently. One aspect of this managerial task is to efficiently use manpower resources. This is aided by an accurate and detailed analysis of the mission, breaking it into integral subtasks, and grouping similar subtasks into man-sized units so that each employee has a job which requires use of his highest level of ability. This factoring of subtasks is part of the function of determining operational requirements for manpower skills.

In practice, this determination is not a rigid, formalized procedure. Rather, each manager's approach may be as different as his personality. For some skills, definite standards have been established linking the volume and kind of work to the number and skills of workers--for example switchboard operators or engine mechanics. But the work of

scientists and engineers does not lend itself to such precise definition and delimitation. Consequently, management has a much more active and responsible role in the establishment of requirements for scientific and engineering services.

Purpose

The objective of the research was to discover, describe, and analyze the methods and procedures used by managers to establish requirements for scientific and engineering services.

This description, in Chapter III, reveals that there are a number of "determinants" used by managers to establish these requirements. It also points out that most managers are only vaguely aware of the existence, importance, and relevance of these determinants. In support of the research objective this paper reports the nature of these determinants to convince the reader that they are actually being used and to emphasize that management is not overtly cognizant of their use.

Since the demand for scientific and engineering services is somewhat higher than the supply, it was conjectured that the requirements for such services may be overstated. That is, scientists and engineers may be employed to perform tasks that could be accomplished by other personnel or equipment. To determine if these requirements are overstated, data were gathered to describe the methods and procedures that managers use to establish requirements for scientific and engineering services.

But it was immediately realized that the determination of whether requirements are overstated is a matter of judgment. To make this determination, some type of norm or standard should be used to establish

the definition of a correct statement of requirements. To this end such a standard was sought, but none was found. Consequently a standard is proposed in Chapter IV.

Using this standard conclusions are drawn and recommendations are made for improving the present methods and procedures so that requirements for scientific and engineering services can be stated accurately.

Scope

The general problem of the shortage of sceintists and engineers is discussed in Chapter II primarily to explain to the reader the origin, importance and impact of this problem. One of several solutions to this problem is to improve the utilization of scientists and engineers thereby accomplishing two independent results. First, their productivity may be increased and second, since they may be more satisfied with their work, they should tend to remain longer in the technical field. Improvement of their utilization can be accomplished by employing less technically qualified personnel to support them. Although this is not the only method of improving utilization, it is the one of particular interest to this thesis, because from it is derived the responsibility of management to allocate tasks to individuals such that their highest level of ability is continually utilized. This is the function of accurately determining operational requirements for manpower skills.

Since the work of scientists and engineers is of a creative nature, the manager can not require a scientist or engineer to produce on demand as he can with a machinist. The establishment of requirements for scientists and engineers is much more difficult than the establishment of requirements for skills that are more precisely definable. Therefore,

management must pay particular attention to its methods of establishing requirements for scientists and engineers. This thesis is primarily concerned with this small, but significant aspect of the general problem of the shortage of scientists and engineers.

It was originally intended to limit this investigation to five specific scientific and engineering disciplines in the Air Force Systems Command (Appendix A). As the research progressed, it became increasingly clear that the distinction between specific disciplines -- mechanical engineer vs. chemist for example -- was irrelevant. It was much more natural to consider only those characteristics of a "scientist-engineer" which were common to any other "scientist-engineer". The distinction is between the scientist-engineer and those personnel which support him with skills such as technician, clerk, secretary, computer programmer, and manager.

The limitation to the Air Force Systems Command (Systems Command) was also somewhat irrelevant. In general, all scientists and engineers in the United States have similar characteristics. Since these characteristics constituted the primary focus of attention, the results of this research are applicable to establishing technical manpower requirements in many environments. The facilities available for detailed study for the most part did belong to the Systems Command. Therefore, the results are biased somewhat toward this particular organization. Since the Systems Command units at Wright-Patterson Air Force Base are primarily involved with research and development (R&D), the results are also biased toward the scientist-engineer working in an R&D environment. This analysis makes no distinction between the military and civilian scientist-engineer.

Although the study is most definitely concerned with scientists and engineers, the reader may find the results applicable to other manpower skills.

Importance

The importance of studying this problem has been aptly expressed by several authorities in this field:

Mr. Vincent E. Holland of Westinghouse Electric Corporation:

> If our country is going to continue to be a world leader, if our national economy is going to continue to expand, if our companies are to continue to compete, then we educational and business leaders have a continuous challenge to face up to the constantly changing responsibilities that we have for the proper training, placement and utilization of technical people (Ref 42:71).

General Bernard Schriever:

> The problem of retaining qualified junior officers is clearly the most important problem facing this Command (Air Force Systems Command) and the Air Force in the future (Ref 5:i).

Mr. Donald T. Jones of North American Aviation:

> The creative engineer longs for recognition and challenging assignments, and he needs opportunities to improve and sharpen his own skills. When these conditions are met, his sense of accomplishment, job performance and overall worth to himself, his company, and society in general are at their peak (Ref 47:18).

Eugene Raudsepp in his book, Managing Creative Scientists and Engineers:

> Since this shortage of highly skilled technical talent by all indications is going to be with us for decades to come, the only way we can insure unhampered future growth and productivity is to find more efficient and effective ways of managing, utilizing, and motivating creative professionals (Ref 91:viii).

This may sound like a big challenge, but consider the rewards: William J. Torpey of the Office of Civil and Defense Mobilization estimated that a 5% improvement in the utilization of scientists and

engineers would add to our effective professional forces as much as all college graduates who complete their training in a single year (Ref 95: 106). In a recent survey of engineers in the Air Force Logistics Command, Benton and Stanton found that "62 percent of the engineers state that at least one quarter of their time is spent on duties which do not require a technical or special knowledge of their profession" (Ref 12:96). Considering the recent budget reductions by Congress and resulting manpower reductions in the armed forces, it is even more important today that those resources still available be used to the utmost efficiency.

It has now been established that efficient utilization of scientists and engineers in an important concern. It is not enough to admonish managers to do a better job of utilizing their personnel. This has often been done (Ref 47:19) and the problem still persists. Obviously, then, this is not the most effective method of improving utilization. Managers need some specific guidance as to HOW to utilize their personnel more efficiently. One specific method is to teach the manager to analyze his tasks to be performed so that he can accurately and objectively determine exactly what skills are needed to accomplish those tasks. Additionally, guidelines must be established so that he can judge the legitimacy of his determination on the basis of the overall objectives of the organization. This can result in an accurate statement of requirements for scientific and engineering services.

Definitions and Assumptions

The term "scientist-engineer" will be used in this paper to refer to the person who has a college degree (or an accepted equivalent) in

some technical area and is currently working in a job that requires the application or possession of this technical background. The scientist-engineer who has become a manager constitutes a "grey area" in this concept. For the purposes of this study, this person will be included as a scientist-engineer if he is assigned to a task because he is expected to use his scientific or engineering talent in the accomplishment of that task.

The scientist-engineer often performs tasks that do not require his specialized skill and ability. It is assumed that these tasks can be accomplished by either a technician or an administrative assistant. In general, a technician is considered to be a person who can understand and apply some of the technical aspects of the scientist-engineer's work whereas the administrative assistant handles some of his paperwork, clerical, and administrative details. All support personnel are herein considered to fall in one of these two categories for ease of discussion rather than to rigidly define their work. That is, secretaries, clerks, computer programmers, laboratory machinists, etc. will all be considered support to the scientist-engineer and the reader can decide for himself if a particular skill would fit better under "technician" or "administrative assistant".

Research Methodology

To accomplish the purposes of the research(i.e., discover, describe, and analyze the methods and procedures used by managers to establish requirements for scientific and engineering services) three types of data sources were used. First, the literature available concerning this subject was reviewed for general background purposes. Second, letters

were mailed to industrial firms, professional societies, and governmental agencies asking for information describing their methods and procedures. And third, interviews were conducted with managers, mostly at Wright-Patterson Air Force Base, who have the responsibility to establish requirements for scientific and engineering services to determine their methods and procedures. A standard for judging the overstatement of requirements for scientists and engineers was also sought in all of these data sources.

Hypothesis. In the section entitled "Purpose" it was explained that to judge the overstatement of requirements for scientific and engineering services a standard should be used. The hypothesis is concerned with discovering such a standard and is stated:

> There is a standard or guideline which aids managers in establishing requirements for scientific and engineering services.

As mentioned in the section entitled "Scope" the facilities available to this study were primarily the R&D environment in selected units of the Systems Command. In reality, this hypothesis is tested only in this environment, but from the review of the literature and from the replies to letters, it is this author's opinion that for the purposes of this paper the R&D environment of the Systems Command is somewhat typical of any environment where scientists and engineers are employed.

There are no formal statistical tests of this hypothesis. Rather, data are presented and conclusions concerning its validity are logically drawn.

Acceptance of this hypothesis requires the discovery of a standard. It was felt that if a standard did exist, it would be revealed in one of the above data sources.

Literature Review. Literature concerning the shortage of scientists and engineers goes back to the post World War II years and covers a wide variety of aspects and approaches to this problem. A review of the first section in the bibliography will show the reader the many subjects, authors, and organizations that have been involved with this problem. The next chapter, entitled "Background of the Problem", is included to explain in detail some of these many facets so that the reader can appreciate the importance and size of the problem of the shortage of scientists and engineers. The chapter then presents one possible solution to this problem--better utilization of scientists and engineers--to describe what other people have done with this solution and to emphasize its importance. Finally, Chapter II describes the attempts others have made to determine manpower requirements. This review of the literature is presented to show its wide range and to indicate that few workable solutions have been developed.

Letters. Once the efforts of the past had been reviewed, it was felt important to be aware of the efforts presently applied. To learn of these, information was requested from sixty-seven industrial firms, four not-for-profit firms, sixteen professional societies and associations and six federal governmental agencies (Appendix B). These four groups of organizations were chosen because it was felt they would adequately span management of scientists and engineers in R&D environments in the United States. The total number of letters sent was limited by the time available and effort required to address and mail them and to read and digest the replies. It was expected that replies would be received from about thirty to forty percent of the letters mailed. It was felt that this quantity would be sufficient to determine

current practices in non-Air Force organizations and to reveal the use of a standard to judge the overstatement of requirements. The decision as to which specific organizations letters were to be sent was based on the desire to cover many different types of organizations. Industrial firms were chosen primarily from a list of those companies that were awarded government contracts in 1965 (a readily available list) (Ref: 36). It was desired to cover as wide a variety of industries and sizes of firms as possible. Not-for-profit firms who do business with the U. S. Government were chosen on the basis of readily available addresses. Professional societies were chosen to represent the various scientific and engineering disciplines. And other governmental agencies were chosen to span those that substantially use scientists and engineers in an R&D environment. Appendix A displays the basic content of the letter, Appendix B lists those individual organizations that received a copy of the letter and Appendix C is a statistical summary of the number of letters sent and replies received. Most letters were mailed in June 1969, but some replies suggested other sources of information, so similar letters were sent to these later in the summer of 1969. The individual respondents who are specifically given credit for their ideas and quotations in this paper are listed in the second section of the bibliography.

Interviews. To determine the practices used in the Air Force, specifically in the Air Force Systems Command, interviews were held with more than fifty persons. Some of these interviews were not pertinant to the subject of determining requirements for scientists and engineers, but did provide background impressions and ideas to the author. It was desired to interview managers who had the responsibility for establishing

requirements for scientists and engineers. These were often first line managers, but sometimes higher level managers were very helpful. The third section in the bibliography lists those twenty-seven interviewees to which credit is given for ideas or quotations in this paper. For the most part, these interviewees provided the most helpful and pertinent information, but the other twenty-five or so did leave ideas and impressions which were assimilated by the author and strengthened his understanding of the present practices, procedures, and methods used in the R&D environment of the Systems Command.

The interview was open-ended and unstructured. The interviewee was told the basic purpose of the research and the intent of the interview and then asked to expound. Often the discussion would lead off on a tangent. Although the author usually was able to redirect the course of the interview, some interviews ended with no data pertinent to the establishment of requirements for scientists and engineers.

Most interviews were conducted in person and lasted about one hour. Some interviews were conducted by telephone and were as short as five minutes and as long as an hour.

Results of the interviews and letters are collected and presented in Chapter III, "How Requirements are Determined Today".

II. Background of the Problem

This chapter presents the basis for the research described in Chapter III. Here, the basic problem of the "shortage of scientists and engineers" is explained from its origin for the reader to obtain an appreciation for the importance and relevance of manpower determinants to the Systems Command, the Air Force, and the United States. This chapter serves the purposes of showing the reader the variety of authors and literature concerning this subject, the wide range of approaches that have been undertaken, and the fact that standardizing scientific and engineering manpower determinants is such an elusive task, that most, if not all, approaches circumvent this problem and address themselves to more manageable, but not necessarily more important, problems.

The Shortage of Scientists and Engineers

The demands of World War II for new and better products, processes, and methods together with the government's willingness to spend money on new technology created a high demand for scientists and engineers. To meet this demand, more and more college freshmen enrolled in scientific and engineering courses. Because of the four years required for training there was a shortage immediately following the war, but soon, there were many scientists and engineers to fill the post war demand. The shortage was over and young men were counseled against scientific and engineering careers. The time lag was just enough to create a shortage again at the outbreak of the Korean War. The educators realized their mistake and have ever since advocated the technical professions (Ref 12: 1). The continued limited war and peace time prosperity has kept the demand for new technology at a high level.

Shortly after the outbreak of hostilities in Korea, it was widely believed that the anticipated increase in defense spending would cause serious shortages of human resources. In late 1952 the Director of the Office of Defense Mobilization realized that the manpower needs "have been met to date without great strain--except for persistent shortages of engineers, scientists, and other professional people..." (Ref 6[illegible]:142).

To cope with this problem, several organizations were formed to discover possible solutions to the problem. In 1953 the National Manpower Council was established to

> evaluate manpower problems of major concern to the country in this period of enduring emergency and to recommend constructive policies for their solution (Ref 69:vii).

A similar organization, the President's Committee on Scientists and Engineers was established in 1957 to

> coordinate and stimulate the nation's efforts to meet the growing needs for qualified scientific and engineering manpower (Ref 101:99).

In 1961 the Standing Committee of the Federal Council for Science and Technology began actively studying the environment of federal laboratories in an attempt to make them attractive and satisfying places of employment for scientists and engineers and to improve the efficiency and effective utilization of their staff (Ref 34:1). And the Engineering Manpower Commission was organized to develop programs to promote the most effective utilization of engineers in support of the nation's health, safety, and interest (Ref 33:3).

The efforts of these organizations were based on the belief that there was in fact a shortage of engineers and scientists. The magazines were full of ads for technical people (Ref 51:26); the increase [illegible] salaries for scientists and engineers rose sharply and disproportionately

(Ref 27:1; 67:144). Even President Kennedy in 1962 expressed concern that

> one of the most critical problems facing this nation is the inadequacy of supply of scientific and technical manpower to satisfy the expanding requirements for this country's research and development efforts in the near future (Ref 75:1).

Definition of "Shortage". To examine the meaning of a "shortage" at this point would give the reader a critical and definite concept of the type of shortage concerned herein.

DeHaven of the Rand Corporation has approached this subject by discussing a variety of concepts of "shortage". Sometimes a "shortage" is used to mean absolute scarcity. Thus, water is "short" in the middle of the Sahara Desert. In 1953 there were 84,000 dentists and 633,000 engineers employed in the United States. If relative scarcity, then, is the criterion of "shortage", dentists are "shorter" than engineers. Sometimes the word "shortage" is used to indicate any reduction in supply to which we have become accustomed. Thus, "rainfall is unusually light this year, so water will be short". Sometimes a "shortage" is said to exist when monopolistic or other practices occur which artificially limit the supply. Thus, consumer goods are "short" in Russia because the government limits the production of these items (Ref 27:3). Blank and Stiegler suggest that a shortage sometimes occurs when the supply is less than the amount declared by some established criterion (Ref 13:23).

The strict economic concept of a "shortage" would be a higher demand than supply at the current market price (Ref 9; 13:23; 27:5; 67:11). Blank and Steigler go one step further to suggest that "a shortage exists when the number of workers available (the supply)

increases less rapidly than the number demanded at the salary paid in the recent past" (Ref 13:24).

It is readily realized that there is neither an absolute scarcity or a relative scarcity of scientists and engineers in the United States. DeHaven points out that there are no attempts to limit the numbers of students entering science or engineering courses or other artificial limitations of the supply. Rather, science and engineering today is actively promoted by professionals, educators and businessmen (Ref 27:4). There is no national criterion dictating the number of scientists and engineers although many individual firms and offices have established their own criteria.

But there has been a reduction in the supply to which we have become accustomed. Benton and Stanton report that in 1950 our colleges graduated 50,000 engineers, in 1960, 38,000, and in 1962, only 36,500 (Ref 12:2). More recently, the number of annual graduates has leveled off to about 35,000 (Ref 163). Although there is evidence that the number of yearly graduates will begin to increase, 40,000 job openings are expected annually through the 1970's (Ref 108) indicating that the increase in supply will be less than the increase in demand.

Reasons for the Shortage. It may be recognized that indeed there is a shortage of scientists and engineers in the United States. A combination of many factors has contributed to this shortage. They include 1) a low birth rate population of the pre-World War II years now serving a high birth rate population (Ref 101:98); 2) expansion of industry to meet the demands for additional goods and services; 3) an increasingly larger amount of engineering time required for the development of complex industrial products and processes; 4) expected

continued growth of expenditures for R&D (Ref 109:73); 5) revolutionary scientific discoveries; 6) the national defense effort; 7) the needs of other developing nations (Ref 59:96); and 8) the present war in Southeast Asia encouraging a larger number of scientists and engineers to go on to graduate school (Ref 163). DeHaven felt that a reason for the shortage was that

> ...the huge government expenditures for weapon systems development and production has already sopped up so many physical scientist and engineers and the continued program requires so many more that a "shortage" of those trained categories exists (Ref 27:1).

It has been recognized that the supply available to the Air Force is even shorter than that available to the nation. In June 1967 General Ferguson, Commander of the Air Force Systems Command, addressed a letter to General McConnell, Air Force Chief of Staff, concerning a "better balance and a more equitable distribution of the scarce S&DE (Scientific and Development Engineering) officer talent we have in the Air Force today" (Ref 35). In reply, the Director of Manpower and Organization, Headquarters U. S. Air Force (AFOMO) stated that "the responsibility of AFOMO to keep the authorization of these 'limited resource' skills in proper balance involves recognition of the following prime factors:

a. The requirement for S&DE officers, as expressed by the major commands, is steadily increasing.

b. The national resource for S&DE personnel that is available to the USAF is decreasing" (Ref 100).

Drysdale of the Personnel Research Laboratory realized that a cause of this problem is that "the total demand for high quality scientific and technical personnel exceeds the supply and the cream of the supply

goes where it finds the most desirable compensation" (Ref 30:2). A significant portion of an individual's compensation is his job satisfaction. Although the term "job satisfaction" provokes a variety of ideas and concepts, one aspect pertinent to scientists and engineers is the fulfillment that comes from continually delving into challenging work assignments. Similarly, the scientist-engineer is dissatisfied when he is forced to perform duties which he feels are degrading and a waste of his time. A 1966 Department of Defense study concluded that "job satisfaction...is the most important single factor influencing junior officers to remain in Service beyond their obligated tours..." (Ref 50:1). Davis reports the results of a survey that found that "with scientists in the Federal Government the most serious problem is an inadequate number of trained technicians" (Ref 26:290). And Benton and Stanton in their research concluded that "the results of these analyses indicate that there exists a less than optimal usage of engineers in industry, the United States Air Force and the Air Force Logistics Command. This is one of the contributing factors to the apparent shortage of engineers" (Ref 12:xi). If the utilization of the scientists and engineers in the Air Force could be improved, not only would more efficiency be recovered from the ones available, but more would become available through a decrease in attrition.

Solutions to the Shortage Problem. Over the years, there have been many suggestions to solve the problem of the shortage of scientists and engineers. In the 1950's when the problem was first recognized, the immediately obvious solution was to increase the supply by graduating more people each year. This of course, was dependent on both the rate at which educational facilities could expand and upon the number of

young people electing to prepare for the scientific and engineering professions (Ref 110:105). This was still felt to be an important solution in 1963. A manpower report to the President stated that "the expected large imbalances between personnel requirements and supply point to the need for a strong national effort to ... attract more students into engineering schools and to reduce the attrition rate in these schools" (Ref 110:107).

But back in 1956 the National Science Foundation felt that "the major factor in the current shortage of scientists and engineers, in our opinion, is an increase in demand, rather than a shortage in supply" (Ref 73:33). Whether it is an increase in demand or a shortage in supply, the net result continues to be that there are not enough scientists and engineers to fill the demand at the present market price.

The point of DeHaven's article (Ref 27) was that the federal government controls the salaries of the majority of the nation's scientists and engineers either directly through federal employment or indirectly through approval of the cost of a contract (which includes the salaries of scientists and engineers). The government of course keeps this cost as low as possible. The other companies that don't have government contracts can pay just a little bit more, taking the best scientists and engineers from government work. The net result is that since many scientists and engineers are paid less than they are worth, it is economical to use them to perform technician's and administrative support tasks rather than hire slightly cheaper help to accomplish these functions. If, on the other hand, free competition were to prevail, the salary paid to scientists and engineers would be much higher and management would be more concerned about how scientists and engineers used

their high-priced talent. Additionally, many more people would want to enter the scientific and engineering careers. To alleviate this situation, DeHaven suggests that

> If managers decide the best course for their organization is to pay high prices for high caliber engineers and scientists and maintain a high ratio of technicians to professionals, this course should be perfectly open to them....The contract should be such to free the market for scientists and engineers by restoring managerial perogatives to the entrepreneur (Ref 27:14,15).

Another suggestion concerns the salary and status symbols given scientists and engineers. Walters suggests

> ...recognize the principle that scientific and technical contributions are as important as those made by management personnel.... Make the higher salaries available to top technical personnel without requiring them to shift to management occupations (Ref 116:393).

Orth has a similar suggestion, but he feels that there ought to be two categories of scientists and engineers--operating and administrative. The operating engineer is the man who chooses to remain a technical specialist. Give him the status he requires and the rewards he would be happy to accept. The administrative engineer should be a resource person; his major function should be helping rather than directing. His job is to release the creative ability of the operating engineer (Ref 81:130).

In 1963 the Directorate of Civilian Personnel, Headquarters U. S. Air Force published a study which suggested

> To reduce or possibly negate the effects of the skills inequality, one approach is to plan remedial action within the framework of administrative and management areas of the Air Force. These activities would have as their goal increased productivity through differential selection, placement, promotion and retention of scientists and engineers. The differentiation would be based upon predictions of productivity which in turn are developed through the identification of characteristics which define quality performance among scientists and engineers (Ref 96:1).

Finally, a common suggestion to solve the shortage of scientists and engineers is to improve the efficiency of their utilization. This involves the concept that the actual numbers of scientists and engineers is not the real concern, rather it is the shortage of competent scientific and engineering services (Ref 51:24). Improved utilization is merely another way of expressing the idea of receiving more scientific and engineering services from the same number of scientist and engineers.

Utilization of Scientists and Engineers

It has been recognized that an improvement in the utilization of scientists and engineers is an important and plausible way to increase not only their numbers but their productivity as well. The National Manpower Council concluded a 1953 conference by agreeing that

> Improving the utilization of engineers is often more difficult than it seems. It is not a matter of techniques or simple rules, but of dealing with people who have their own aims, who insist on making their own mistakes and who do not always want to make the fullest use of their abilities in directions desired by management. When put into effect, moreover, suggested improvements generally reveal unexpected resistances (Ref 69:93).

Even though it is admittedly a difficult problem to solve, its importance provides impetus to at least attempt a solution. To get a better understanding of possible solutions, it would first be instructive to examine some of the more common causes of poor utilization.

Causes of Poor Utilization. Placing the skills of a scientist-engineer in the job of the manager is an obvious misuse of technical expertise if the managerial job has little technical content. It may be argued that the manager must have the technical background to do his job. This point is debatable in many instances and serves only to circumvent

the fact that the technical skills are not being properly used.

Another important difficulty is teaching the scientists and engineers to use the technicians and administrative assistants available to them. The scientist-engineer can not and should not try to do the whole job himself. His primary responsibility is to plan the work and to work the plan (Ref 59:97; 44:125). But many wish they could get support. Often technicians and administrative assistants are in short supply (Ref 26:270; 166). Additionally, especially in the Air Force, there is a considerable time lag between the request for and the receipt of additional manpower (Ref 12:42; 144).

Since the scientist-engineer usually possesses the skills of the support personnel, to a limited degree at least, he is capable of getting the job done although it may take considerably longer (Ref 21:90). This problem becomes more pronounced when top management decides that dollars could be saved by decreasing overhead and eliminating support jobs (i.e. technicians, secretaries, clerks, administrative assistants, etc). The first line supervisors find that the work still has to be done and the only ones left to do it are the scientists and engineers (Ref 157:161).

Top management in the Air Force controls the number of these support jobs through its control of manpower numbers and skills. Air Force managers must cope with this constraint as well as an independent budgetary constraint, whereas many managers in private industry pay for their manpower from their budget as they do for their raw materials and equipment. The effect of several independent constraints on the manager has been described by Nicolai of the Office of the Director of Defense Research and Engineering. In a theoretical analysis using

indifference curves and maximizing principles of economic analysis, he demonstrated how the controls by top management over manpower spaces as well as the budget prevent the line manager from optimizing his organizational effectiveness (Ref 79:1).

To many authors, the greatest cause of poor utilization of scientists and engineers is the manager himself (Ref 8; 12:64,90; 14:191; 15:5; 42:69; 69:85). Consider this statement:

> We still have to convince some managers that they should scrutinize their engineering departments and maximize the utilization of their engineers by assigning as much work as practical to technicians (Ref 42:69).

Or this one:

> In most companies engineering work is not being evaluated by management in order to determine what parts of it can or should be done by people of lesser or different training (Ref 8:22).

Again:

> The supervisors most likely do not know precisely what any one subordinate does task by task (Ref 12:91).

And in an article admonishing scientist-managers, Barrows stated that the scientific managers

> ...utilize technical people in functions for which they are not trained, ranging from "parts chasing" to top management. This situation alone bleeds off an immeasurable amount of talent so vitally essential. Another problem was the tendency on the part of most R&D organizations to meet the frequent problem of overspent (usually referred to as "underfunded") budgets by cutting back on support personnel while maintaining large numbers of scientists and engineers to preserve a "basic capability for research". This adds to the problem of the nonutilization of technical people (Ref 14:191).

An excuse for this attitude is offered by Blood who states that

> ...management has been preoccupied with the many other areas that are important to a corporation's going operations. Technical activities have assumed a position of major importance in the total management picture only relatively

recently, and this has resulted in a degree of neglect (Ref 15:5).

Solutions for Poor Utilization. Some of the causes of poor utilization immediately suggest obvious possible solutions. During the literature review it was found that many authors had ideas concerning improved utilization, but the literature describing applications of these ideas was sparse. This may be due to the fact that each individual circumstance has its own peculiarities which limit the use of the particular solution on a wide scale, but it is the author's impression from reviewing the literature that management has not been vitally concerned with effecting a solution and, therefore, the problems persist.

One of the often mentioned solutions in the literature is that management should become genuinely interested in improving utilization (Ref 15:105; 21:88; 40:191; 47:19; 115:18; 116:219). For example, Wagner addressed a Manpower Utilization Conference in Buffalo, New York in 1961 by saying:

> To the industrial people in this audience I say that one of the greatest contributions you can make to efficient use of manpower is to identify and train managers....If we have good managers, our manpower will be used efficiently....The square pegs will be put in the square holes...by a good manager (Ref 114:4).

Management has several direct responsibilities with respect to efficient manpower utilization. One of these is to motivate the employees to perform well (Ref 40:191; 85:7; 91). It has been found that if an individual is given more and more responsibility, he is willing and able to accept it and is often more satisfied with his job because of it (Ref 69:37, 78, 85). Keeping scientists and engineers satisfied also requires an effective communication system whereby the manager is fully aware of his subordinate's problems, concerns, hopes and desires

(Ref 61:34). Often scientists and engineers leave their jobs for management jobs to achieve more status, pay, etc. This not only puts a drain on the technical skills, but sometimes produces relatively incompetent managers who can perpetuate the utilization problem (Ref 14:191; 69:97; 80:127; 95:106).

Some managers have found that the "scientific management" approach is advantageous for improved utilization. A computerized skill inventory of all scientists and engineers in the firm affords instantaneous access to a desired skill (Ref 18; 44:127, 92; 115:16, 18; 116:89). With an accurate knowledge of employees' skills, abilities and interests, the manager can expect his employee to take an active interest in his job, contribute more and get more satisfaction from his efforts (Ref 47:19). Operations research methods have also become important. A Navy Lieutenant Commander has developed a planning model for optimum utilization of manpower resources (Ref 23). This falls in line with a recent Department of Defense Directive that requires a systematic economic analysis when making resource allocation decisions concerning men, money, and material (Ref 29). But the "scientific" solution thus obtained is not the primary advantage. Rather, the manager is forced to explicitly define the constraints and criteria operating on the problem. Often this calls into question the existing policies and goals in an objective way not otherwise possible (Ref 31:3).

Another suggestion for improved utilization of scientists and engineers is to retrain the older technical personnel in modern concepts --for example, electronic tube design to transistor design (Ref 40:191; 69:96).

Finally, one of the most obvious ways of improving the utilization

of scientists and engineers is to provide them with support--comput test equipment, clerks, technicians and administrative assistants (15:155; 44:126; 114):

> Probably the first and most obvious way to conserve available scientific personnel is to reduce the diversion of professional talent to non professional activities. This suggestion means the delegation of sub professional jobs to sub professional people, clerical jobs to clerical people, minor administrative jobs to administrative assistants, and so on (Ref 40:195).

Hoyt expressed the importance of this concept by stating:

> It should be obvious that from the viewpoint of efficient use of the talent and education possessed by the professional per sonnel to whom is entrusted the research that is to be perfor there should be assigned to help or support these professiona other individuals with lower-level mental abilities or with more highly developed manual skills. The advantages of this combination of professional and technical support personnel are clear: (1) each works continuously in the upper ranges of his particular level of capability, is constantly challenged by his work, and derives a sense of accomplishment and personal growth from it; and (2) lower-level skills are performed by individuals who are paid accordingly, resulting in a lower overall cost of the project (Ref 44:124).

It may be argued that support people are in fact being utili

In 1953 it was reported that

> ...some shortages of scientific and professional personnel have been alleviated by improvements in the utilization of manpower which have had the effect of stretching the existing supply. Thus auxiliary workers have been employed to relieve qualified engineers from routine tasks so that they can perform at a higher level of skill (Ref 67:14).

But the problem still persists. In 1963, Green reported

> A rough survey suggested that, despite the progress of recent years, somewhere between one third and one quarter of our professional personnel's time is spent on work that coul be done by technical aids, with a somewhat smaller amount spent on work that could be performed by clerks or secretari (Ref 40:196).

The American Society of Mechanical Engineers reported a survey o engineers asking "What measures do you think should be taken to

the shortage of engineering manpower?" The largest single group of the respondents (31%) answered that more technical and clerical help should be provided (Ref 88:20). Finally, from their research last year, Benton and Stanton concluded that "66% of the engineers (in the Air Force Logistics Command) could be more effectively utilized in the performance of their technical duties by a reduction in non-technical work" (Ref 12:100).

In 1965 the Federal Council for Science and Technology surveyed 1025 scientists and engineers in the federal government's R&D laboratories as to their individual satisfaction with their employment and their opinions as to the efficient utilization of the staff. Out of 51 questions, the opinion "I should be given work that utilizes my skills and abilities to a maximum" was rated third in importance. Similarly, the opinion "I should have adequate technical assistance" was rated sixth in importance (Ref 34:5).

There have been similar surveys and studies with similar results (Ref 47:18; 52; 97:325; 103; 106). It is not this author's intent to report on all such surveys, but to indicate that the level of malutilization of scientists' and engineers' skills is still high today and that there is much room for improvement.

Determination of Manpower Requirements

The Need for a Measure of Manpower Requirements. It has been shown that the problem of a shortage of scientists and engineers is important, that it can be at least somewhat alleviated by better utilization, and that improved utilization can be accomplished by providing more technical and administrative support to the scientists and engineers.

The question now arises "How much and exactly what kind of support is best?" It is the thesis of this author that this is the responsibility of the first line supervisor; it is his job to determine the exact manpower requirements. That is, he should analyze his task, break it into its basic elements, decide which subtasks need scientific and engineering skills, technician's skills, clerical skills, etc., and organize these subtasks into man-sized groups so that each individual employee has a full time job performing work of his highest capability.

To perform this function, managers should have some standard or at least some guidelines to aid them in deciding which subtask requires which skill. A major purpose of the review of the literature was to discover and identify such a standard or guideline. None was found. Instead, the review of the literature emphasized that many people had considered the problem of the shortage of scientists and engineers, some people had advocated plausible suggestions for improving it, a few had attempted to improve it in their own organizations, and several had had some success.

In 1957, the Personnel Laboratory at Lackland Air Force Base, Texas conducted a study to survey available information at that time relative to the shortage of scientists and engineers. Conferences were held with representatives of some of the twenty-nine agencies identified as being concerned with the problem, and reviews were made of the data and publications available on the subject. The results of the investigation indicated that to that date no definite evaluation of the problem had been provided, nor was it likely to be provided with the information available, because "no clear measure of manpower requirements on a national scale is in evidence" (Ref 58:v).

Examples of measures of manpower requirements. How does one measure manpower requirements? There have been several attempts to do just this in recent years. One of the most pertinent is the efforts by the Air Force Management Engineering teams which review and approve all manpower authorizations in the Air Force. To determine overall manpower requirements on a division level, for example, they have developed a Program Estimating Equation which uses past data to predict the amount of manpower required as a function of the number of dollars budgeted (Ref 149). Very simply, one of these equations is of this form:

$$\text{New Manpower} = \frac{\text{new \$ budgeted}}{(\$/\text{man})\ \text{now} + \text{rate of change of } (\$/\text{man})}$$

The rate of change of the dollars per man is based on data from several previous years (Ref 141). It must be emphasized that this explanation is a gross simplification of this model.

Job evaluation has been used for many years to rationalize the internal wage structure for hourly employees in industry. But as a measure of manpower requirements, it is not extremely accurate. Its greatest success is that it compels management to describe and classify positions and to analyze their interrelationships for the purpose of recognizing and correcting anomalies (Ref 83:9). Since the work of scientists and engineers can not be precisely defined, job evaluation has not been applied to scientific and engineering jobs as it has to hourly industrial jobs. But there have been some attempts toward this goal. The U. S. Army employs Method Engineering Surveys which are work sampling studies to determine the exact amount of time spent on extraneous duties (Ref 132). The Personnel Research Laboratory has performed

a job inventory of Air Force officers in the R&D Management Utilization Field (Ref 63) and Electronics Engineers (Ref 64). These inventories have identified most of the major tasks that people in these fields perform. This information should be useful to managers to aid them in matching tasks to be performed with skills available.

The use of mathematical programming, operations research, and computers has also been applied to measure and plan manpower requirements (Ref 7; 22; 25; 28; 31:2; 53; 56; 94; 98; 113). But virtually all of these efforts are concerned with the overall manning function, that is, the total number of employees in an organization. They don't give the manager any guidelines at to how to decide, for example, whether an engineer or a technician would be better suited to accomplish the task in question.

An attempt to have the first line manager determine his requirements and efficiently use his manpower resources has been tried. A concept known as "Man Friday" was initiated at Fort Belvoir, Virginia in 1959 and later was attempted at the Air Force Avionics Laboratory at Wright-Patterson Air Force Base. Ideally, it was desired to employ a college graduate with a degree in business administration and an interest in science or engineering to be a Man Friday. This person would be able to communicate the ideas of management to the scientists and engineers and vice versa. He would perform many of the administrative duties of the scientists and engineers--not only filling out forms, but understanding what information to include on the form. In practice, it was difficult to find a college graduate who was willing to be subordinate to both management and the operative scientists and engineers and who had no ambitions to be promoted to higher responsibility.

Another important difficulty was that a Man Friday would have been considered overhead, and to authorize one Man Friday for every four or five scientist-engineers could not be approved. The concept has since degenerated so that a Man Friday now is typically an experienced secretary working for an entire branch. Her ability is not as great as the ideal Man Friday and she is working for a much larger number of people than ideally desired (Ref 157; 161).

Manpower Requirements in the Air Force. An examination of the official Air Force instructions concerning manpower requirements is appropriate. Air Force Manual 26-3 entitled Air Force Manpower Determinants is concerned with defining the manpower requirements as closely as possible and suggests three basic methods of doing this:

1. Work Center Manning Standard. A Hq. USAF approved, quantitative expression of manpower, by skill, required to accomplish the defined responsibilities of a work center at varying levels of workload volume.

2. Manning Criterion. A Hq. USAF approved quantitative expression of the manpower, by skill, allowed for the performance of work at varying levels of workload volume. (Does not meet the accuracy specifications of a manning standard).

3. Program Estimating Equation. A mathematical equation that uses a broadly based, program oriented, independent variable to forecast and/or program manpower requirements into future time periods (Ref 3:1-1, 1-2).

The role of these manpower determinants are further described:

> By definition, manpower determinants are the family of standards, criteria, and program estimating equations used to determine, control, distribute, and program manpower resources. Standards and criteria are the primary means used. However, there are instances when the workload factor of a standard or criteria is not programmed or programmable and an alternate means is required. To bridge the gap from unprogrammable standards and criteria to the manpower program requires the development of a program estimating equation (Ref 3:1-2).

The use of these determinants is very important in the Air Force since

they "form the basis for developing the Basic Authorization File in the Manpower Allocation and Accounting Subsystem" (Ref 3:1-2). It seems odd then that for the R&D environment in the Air Force, determinants for scientists and engineers have only just recently been estimated with a program estimating equation (Ref 149). But the reason for difficulty in applying these determinants is understandable. AFM 25-5, Management Engineering Proceedures, states that "work center manning standards reflect, at varying workload volumes, the manpower cost of performing a number of reasonably homogeneous activities, grouped into what is called a work center" (Ref 2:1-1). A typical example of this type of work center would be motor vehicle maintenance shop. Clearly the day to day work of scientists and engineers is not "reasonably homogeneous".

A Management Engineering Team (Detachment 31 at the Foreign Technology Division at Wright-Patterson Air Force Base) has recently developed manning criteria for a work center concerned with editing and publishing the documented reports generated by that division (Ref 56; 150). The work there is also much more homogeneous than that which scientists and engineers normally perform.

It may be argued that the job descriptions outlined in AFM 36-1, Officer Classification Manual, provide adequate determinants of the type of work an electronic engineer (AFSC 2825), for example, is expected to perform. The manual goes into considerable detail. For example, the electronics engineer

> "...engages in continuous development and modification to improve performance and suitability of electronic and electrical equipment and systems. Establishes performance and serviceability requirements for improved electronic and electrical equipment including navigational aids;

> countermeasures; television; guidance and control systems... (Ref 4:A10-39).

This job description is far too general to be of practical assistance to a supervisor in establishing his requirements for engineering skills. It may be noted that the job description does not include duties such as run errands, escort visitors, type letters, gather data, etc. In effect, it is officially expected that these functions are not an inherent part of the job of an electronics engineer.

As has been shown, the official Air Force instructions do not adequately define the manpower requirements for scientists and engineers. Neither do the approaches attempted by various other organizations. In fact, the literature provides no panacea either. Is this task then an impossibility?

To answer this question it was felt that an intimate acquaintance with the present method of determining manpower requirements would be helpful. The literature does suggest some methods being used, but to interview managers in the field who have this responsibility was thought most likely to provide the most accurate answer. The results of these interviews are presented in the next chapter.

III. How Requirements are Determined Today

Chapter II presented a summary of the ideas and solutions that have been suggested and attempted in the past. This chapter describes the proceedure for determining manpower requirements that is actually in use today by managers. This proceedure was gleaned from interviews, from the pertinent information supplied in some of the replies by letter, and occasionally from some of the authoritative literary sources.

Although the author spoke with more than fifty persons concerning this research effort, only 27 are specifically referenced herein. (These are listed in the bibliography.) The conversations with the others did contribute to the author's impressions concerning this subject, but were either not germaine or not specific enough to warrant direct reference. The selection of specific interviewees is discussed in Chapter I under "Research Methodology".

In general, an interview began with an explanation of the overall problem area and a statement of the objective of the research similar to the presentation in Chapter I. The question was then asked, "How do you determine your requirements for scientists and engineers?" In general, the response of the interviewee at this point indicated that the question was unfamiliar enough to suggest that little thought had been given the problem previously. The fact that he had no immediate direct answer indicated that no standard or guideline was overtly in use to aid him in this decision.

A discussion then ensued with the object of getting the interviewee to introspectively analyze his decision process. Often, it was difficult for the interviewee to honestly understand this objective and,

therefore, the interview was only partially successful. But most were able to describe some of the aspects of their concepts of the definition of a scientist-engineer, to contrast him to a technician or an administrative assistant, and to specify some of the considerations they believed were significant in the determination of requirements for scientific and engineering services.

Letters were sent to sixty-seven industrial firms, four not-for-profit firms, sixteen professional societies and associations, and six other federal agencies. (Appendix B) They were addressed directly to the president or chief executive with the request to forward the letter to those subordinates who had the responsibility to establish requirements for scientific and engineering services.

None of the replies suggested that standards or guidelines were overtly used, although one company mentioned "We are just now exploring a Corporate Manpower Requirement System which should give us relevant manpower information in the future" (Ref 126).

The respondents varied considerably in their understanding of the basic problem, but many did try to answer the question by talking around the subject, describing their concepts of a scientist-engineer, and indicating some of the overall determinants of their requirements for scientific and engineering services.

The information gathered during the research consists primarily of a number of specific quotations and broad concepts. The author has interwoven the specific quotations into a context which he believes accurately represents that broad concept which could be considered "typical". This typical concept is based on the characteristics of a scientist-engineer. Therefore, a description of a scientist-engineer is

first presented, followed by other determinants of requirements for scientific and engineering services that the respondents felt to be significant.

It is not intended to imply that any one particular scientist or engineer possesses all of the characteristics mentioned to the utmost degree. Nor, did any one particular manager suggest all determinants listed. Rather, this is a compilation of the views of many persons which will naturally include a wider description than that which would be considered applicable to any particular scientist, engineer, or manager.

Characteristics of a Scientist-Engineer

From the responses of interviewees and letter respondents, it was obvious to the author that one of the most important considerations a manager uses in his establishment of requirements for scientific and engineering services is his basic concept of a scientist-engineer. The author felt that this definition of a scientist-engineer was the primary basis of the manager's decision process. One important question that may be asked is "Do all managers share the same definition of a scientist-engineer?" From the research the author believes that in a very general sense they do. But in a specific sense, each manager has a unique concept based on his own experiences and defines a scientist-engineer in terms of the specific work he performs. Since this study is concerned with all scientists and engineers, the general concept is appropriate and the following characteristics relate to the general definition of a scientist-engineer.

Technical Exp[illegible]. The scientist-engineer is an expert in some

technical area. The scientist-engineer has "technical qualifications" (Ref 162); a "knowledge of engineering" (Ref 144); "the basic textbook knowledge" (Ref 147); "a good understanding of engineering principles, practices, and techniques from both a theoretical and practical point of view" (Ref 104:11); "expertise in some technical area" (Ref 128); and "breadth and depth of knowledge" (Ref 131).

Creativity. Creativity is considered a basic characteristic of a scientist-engineer. It is he who does the "initial creative work" (Ref 154); the "original thinking" (Ref 167). He develops "new phenomena or techniques" (Ref 144; 166; 167) and "develops methods" (Ref 109:70). He must be "creative" (Ref 128; 131) and "innovative" (Ref 130; 131).

Analytic Ability. The scientist-engineer has acquired an ability to think "analytically and precisely" (Ref 163). He has a "general problem solving technique" (Ref 153); an "analytic ability" (Ref 128; 162); "ability to break the task into integral pieces" (Ref 143). This gives him the ability to "identify problems and technical necessities" (Ref 143). He then tends to be "nitpicky and pays attention to details" (Ref 159).

Technical Communication. Many people insisted that a scientist-engineer has the ability to communicate technical information (Ref 145; 148; 153; 162; 163; 166; 167). He can understand not only the terms but also the concepts involved in the transmission of technical ideas. He then has the ability to intelligently communicate with many types of people including other scientists and engineers, contractors, and procurement specialists (Ref 145).

Breadth of Perspective. A "breadth of interest and perspective" (Ref 128) enables the scientist-engineer to apply his technical

expertise in the world which provides an infinite variety of interr .- tionships. He is able to "understand the overall objectives" (Ref .) and can interface his technical solution with 1) "other hardware" (; 147); 2) "availability of materials" (Ref 147) and "manpower" (Ref ; 147; 156); 3) "costs" (Ref 127; 131; 147; 156); 4) "time or schedule (Ref 127; 131; 147; 156); 5) "priority of the program" (Ref 147); 6) "volume of work to be done" (Ref 147); 7), "benefits to be derived" f 147), and "risk involved" (Ref 156), and 8) "technical feasibility" ef 147; 162). The scientist-engineer also has the "initiative to keep to date in his field" (Ref 144; 162) thereby guaranteeing his "knowl ge of available equipment" (Ref 144) and techniques and enhancing his ability to interface the many aspects inherrent in the overall objec tive. This concept of breadth of perspective is sometimes referred as the "ability to think" (Ref 153).

Other Characteristics. Other characteristics of a professional were mentioned by only a few sources and are collected here to indic e that the scientist-engineer is a rather "well rounded" person. Some these other characteristics are: "balance and common sense" (Ref 13 "initiative and resourcefulness" (Ref 104:13); "a professional attit " (Ref 151); "ability to take responsibility" (Ref 167); and "judgment (Ref 104:13; 132; 149).

Scientist-Engineers vs. Support Personnel

To clarify their concept of a scientist-engineer, many responde described what the scientist-engineer is not. That is, they discuss the definition of a technician and an administrative assistant and differentiated these from the scientist-engineer.

Technician. "The technician works in direct support of the scientist or engineer" (Ref 112:728; 155). He does "routine lab tests" (Ref 112:629), "routine, non-creative work" (Ref 154). He adapts "existing procedures or techniques" (Ref 105:22); "adapts and revises established procedures through experimental methods" (Ref 105:22); "operates equipment, makes repetitive measurements, and reduces data to a desired form" (Ref 166). "He assists, takes data, reduces data, and operates desk calculators and adding machines" (Ref 125).

Most people interviewed found it easier to differentiate between a scientist-engineer and a technician than to define a technician outright:

"A scientist-engineer does the thinking work and the technician does the routine work" (Ref 166;167).

"The scientist-engineer does it the first time, the technician the second time" (Ref 167).

"Scientist-engineers are theoreticians, technicians are practitioners; the scientist-engineer develops a peculiar solution whereas the technician applies a standard solution and may modify it slightly" (Ref 147).

"In the field, for example, the technician determines the type of fix while the engineer determines the size or amount of fix" (Ref 147).

"The scientist-engineer gets his education by training, the technician by experience" (Ref 156).

"A scientist-engineer has a college degree whereas a technician does not" (Ref 147; 151; 155; 167).

"The technician notes a change in data, the scientist-engineer recognizes the significance of the change" (Ref 166).

"The scientist-engineer defines the problem and the method of solution and the technician then gets the solution" (Ref 155).

Administrative Assistant. The term "administrative support" refers to the non-technical tasks which are sometimes performed by a scientist-engineer. Administrative support is supplied by people with job titles such as clerk, typist, errand boy, secretary, procurement officer, and

administrative assistant. In this paper, these are all referred to as administrative assistants.

To the question "Why can't an administrative assistant perform an engineering task?", respondents answered:

"Specialized (technical) knowledge is required" (Ref 146).

"Knowledge of engineering methods is required" (Ref 109:70).

"A definition of technical requirements is required" (Ref 143).

"If the job is engineering oriented, an engineer will be able to do it, but a non-engineer may be able to do it" (Ref 156; 159)

"The engineer can understand the significance of the (technical) results better" (Ref 162).

Specific Determinants

This section assimilates some of the specific determinants of requirements for scientific and engineering services used by managers. The first one--past experience of the manager--relates very closely to the manager's definition of a scientist-engineer. The respondents usually spoke of these two concepts together. But past experience includes more than just the concept of a scientist-engineer. The manager uses this definition as a basis, then applies many of the other determinants listed. This decision process is based on judgment and the manager's past experience.

Past Experience. The most popular determinant of requirements for scientific and engineering services was "past experience of the manager" (Ref 122; 132; 133; 134; 140; 144; 147; 149; 150; 154; 156; 158; 165; 166). Some specific replies were:

"Ask other people who are familiar with the way things were done before; relate to similar programs" (Ref 156).

"How did we do it before? How did someone else do it before?"

(Ref 165).

"Analysis of past utilization" (Ref 132).

"The experience of the manager is most important" (Ref 156). The terms "intuition" (Ref 158) and "judgment" (Ref 132; 149) were also used to imply past experience.

A closely related answer was "Look at the job" (Ref 135; 147; 159). "The nature of the function tells the kind and number of skills needed" (Ref 140). "Knowledge of the nature of the work" (Ref 125). "Tailor the manpower to meet the requirements of the job" (Ref 159). The implication here was that it was necessary to first analyze the job to determine its requirements, then, by past experience, the manager could specify what skills were needed.

Several respondents felt that the job descriptions or position descriptions were adequate to establish what manpower skills were necessary (Ref 121; 123; 125; 135; 138; 142; 154; 158). Ling-Temco-Vought, Inc. sent the author documents containing "the guidance, criteria and standards used in the hiring of manpower in our intermediate job grade" (Ref 121). In part, the duties of a Electronic Systems Engineer, for example, are to

> Analyze and/or develop and design major electronic and electrical control components or minor systems for various fields such as automatic navigation or guidance systems, stabilization systems and auto pilots, antenna systems,... (Ref 121).

Flexibility. The idea that the scientist-engineer has the talent and skill to perform the duties of support personnel, to a limited extent at least, was felt by many to be a significant determinant. For example:

"The scientist-engineer is a more flexible person than either a

technician or an administrative assistant" (Ref 162).

"Engineers are adaptable to a wide variety of tasks" (Ref 145).

"The engineer can do a technician's work, but the technician can't do engineering" (Ref 152).

"When you need only one more man, hire an engineer because he's the most versatile" (Ref 163).

"Managers are required to keep the overhead down (a basic Air Force Policy). Therefore, a directive to cut my overall manpower means a cut in support personnel because they are the lease versatile" (Ref 152).

"When the definition of the task is imprecise, the man tends to make his own job. Therefore, specify an engineer because you want the best man for the job" (Ref 166).

"If a technician were given an imprecise job, the chief would have to take time out to train him" (Ref 156).

"Getting the work out is the prime consideration" (Ref 153).

Economics. Economic considerations are essential to industry (Ref 125; 129; 132; 134; 136; 139). They hire scientists and engineers if their budget will allow it. Some Air Force interviewees definitely felt that if they had only a budgetary constraint with no manpower constraint, they would be able to hire the support personnel they felt were required and could possibly release some of their scientists and engineers (Ref 152; 155; 162). On the other hand, a few felt that their overall operation would not be any more efficient with only a monetary constraint (Ref 142).

Availability. Another factor mentioned often was "availability of people to fill the authorizations: (Ref 122; 129; 134; 150; 153; 154; 156; 160; 164; 166). A knowledge of either the skills that were available or the specific persons available to fill a position had an influence on how a requirement was specified. "Sometimes I specify a requirement for an engineer because I know it is difficult to get a good

technician' (Ref 159; 166). "The requirement is sometimes written to fit the qualifications of a specific person who is available" (Ref 122; 156).

Red Tape. The "red tape" involved in getting requirements filled plays a significant role. For example:

"General Air Force policy doesn't question the justification I submit for an engineering position nearly as much as it questions the justification for an administrative assistant" (Ref 159).

"It's easier to get an engineering slot than a technician's slot" (Ref 166).

"I can't let go of my slots during slack time of the year because I won't be able to get them back during the busy times" (Ref 147).

"I have to guess at my future requirements because of the long time lag between a request and the receipt of an engineer" (Ref 144).

Politics. Politics on a local organizational level is also a factor in determining requirements for scientists and engineers:

"Political implications of the Civil Service System" (Ref 149) with respect to specific personnel getting specific positions is an important factor.

"The manager's influence on his superiors to get what he wants" (Ref 163). This refers to the manager's "pull" or "apple polishing" influence on his superiors.

"If another chief engineer of a higher grade and I were both considering hiring the same person, he would be given preference because of his higher grade" (Ref 155).

Prestige. A manager receives a certain amount of prestige by supervising scientists and engineers. "To supervise 17 engineers means the manager gets promoted faster than his peer who supervises just a few engineers" (Ref 151). "You can't have a GS 12 manager supervising a GS 13 engineer" (Ref 147), therefore, the manager is also promoted, whereas if the subordinate was a technician, he would perhaps be a GS 9. "It takes a less competent manager to supervise technicians than it does to supervise engineers" (Ref 155).

Prejudice. In most R&D environments, the manager has an engineering background himself and therefore "likes to surround himself with his own kind" (Ref 147; 151; 159; 166).

Program Priority. The priority of a particular program that requires engineering skills has an interesting effect on the determination of requirements. If the program has a rather high priority it will most probably get all the scientists and engineers requested. And the manager of the program with a very low priority makes a definite effort to hoard the engineers he has since his priority is so low, no one else will do his engineering work. (Ref 132; 133; 147; 161; 163).

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IV. Analysis of Present Methods

Test of the Hypothesis

In this section the hypothesis will be tested. As stated in Chapter I it is:

> There is a standard or guideline which aids managers in establishing requirements for scientific and engineering services.

Of ninety-three letters mailed, forty-six replies were received. (Appendices B and C). Most of the respondents concentrated on job descriptions, performance evaluations and selection of the individual scientists and engineers, but in so doing were able to express a philosophy concerning the important characteristics of a scientist-engineer. Few replies referred specifically to factors important in the determination of manpower requirements and none referred to specific guidelines overtly used by managers in this decision.

Similarly, the interviews centered around the definition of a scientist-engineer and some of the specific determinants used to establish requirements for scientists and engineers, but none indicated an overt awareness of any guidelines for this determination.

Of course, it cannot be said that standards do not exist but it is believed that the sample questioned represents a sufficiently wide variety of managers, fields, and occupations, that it would reveal the existence of any standards, criteria, or guidelines. These findings, together with the absence of any standards in the literature indicate that no explicit, objective standard exists. Since the hypothesis, therefore, cannot be accepted it is concluded that a standard or guideline which aids managers in establishing requirements for professional

scientific and engineering services does not exist.

Since no standard is commonly used by managers, it would be significant to examine the method they do use to determine scientific and engineering manpower requirements to see if it is logical, rational, and legitimate. From this examination, a standard will be proposed and whether or not requirements are overstated will be judged.

From this point, the discussion and conclusions will be biased toward the R&D environment in the Air Force Systems Command. Managers in other environments will find many of these aspects applicable to their particular situations and can modify the results appropriately.

Characteristics of a Scientist-Engineer

As seen in Chapter III one of the most important determinants of requirements for scientists and engineers was the "past experience" of the person charged with the responsibility of establishing technical manpower requirements. Interviewees were able to express that they based their determination of manpower requirements on past experiences, but most were unable to explain that past experience in detail. By the assimilation of all the data the author has what he believes to be an accurate description of this "past experience".

It begins with the concept of a college education. In the minds of the respondents, there was obviously a definite distinction between a "college graduate" and a "non-college graduate". The diploma is not the most accurate criterion though because many respondents were quick to point out that there were several older people who were considered to have the equivalent of a college degree. What is it about a college education (or its equivalent) that makes such an important distinction

between people? The overall goal of a college education is expressed by one undergraduate college in its catalog:

> The General Studies requirements are designed to expand the capabilities of students to become involved, with interest and understanding, with the full range of phenomena and experience available to man (Ref 46:27).

By rereading and reflecting on this quotation, the reader will be able to understand that the real significant difference between a college graduate and a non-college graduate is the "potential to grow" (Ref 155). This is the ability to expand his horizons--his capability of finding, understanding, and enjoying new experiences and phenomena.

Similarly, the Ohio State University catalog states that

> ...The development of a student's knowledge requires not only introducing him to a wide range of facts about man and the Universe, but stimulating him to search for relationships and human significance in these facts, to the end that he acquire the definite interests which are necessary for continuous intellectual growth and the enjoyment of the intellectual life. At the same time it involves not only teaching him how to recognize a problem, its elements, its relationships and implications and how to bring the whole into clear perspective, but also encouraging him to re-examine problems in the light of new conditions (Ref 82:131).

On a practical level the college graduate is acquainted with the basic technique of problem solving which takes into consideration the infinite interactions and implications of the alternative solutions.

These skills and abilities that are learned in a college curriculum are often referred to as the "ability to think". That person who has not completed a baccalaureate program but is considered by his peers to have the characteristics of a college graduate is perceived to have acquired this "ability to think" through many years of experience. The advantage of higher education is to compress the time required to achieve this ability. In a letter to the author, Curtis of the General

Electric Company explained that a non-degree holding engineer may be

> ...the rare outstanding individual without a degree who has had extensive and clearly identifiable professional engineering experience and who is now doing engineering work. An individual who has become skilled in one narrow technical specialty through many years of practical experience would not necessarily qualify for an engineering title unless he possessed technical knowledge applicable to other engineering work which might be reasonably expected of a graduate engineer (Ref 124).

It is the author's impression that the characteristic of a scientist-engineer referred to as "breadth of perspective" in Chapter III actually was meant to express the above concept of a college graduate. Respondents were not able to explicitly express these ideas probably because they had never been required to think consciously and objectively about them. But it was apparent that they were aware that the person with a college education was quite different from the high school graduate. Primarily, there are two general skills under consideration. One is that skill represented by a college education and the other is the skill represented by the technical characteristics of a scientist-engineer (i.e. technical expertise, creativity, analytic ability, and ability to communicate technical concepts). In this general, oversimplified model, the technician has the technical skills, the administrative assistant has the college education, and the scientist-engineer has both. Of course, in reality, most technicians don't have technical skills identical to the scientist-engineer and many administrative assistants don't have that quality implied by a college education. But it can be appreciated that the scientist-engineer who has the combination of both these skills is a very flexible individual of much more value to the manager than either of the other two. It is no wonder that managers prefer to request scientists and

engineers rather than support personnel.

When a respondent answered that he determined manpower requirements on the basis of past experience, the job description, or "I just look at the job", the author felt that he was comparing the requirements that he saw in the job to the above concept of the definition of a scientist-engineer. If he thought that the job required the "ability to think", it, therefore, required a college graduate. Additionally, if it involved a scientific or engineering technicality, he would assume that an administrative assistant with a B.A. degree could not handle it.

In practice, this decision process doesn't take nearly as long as it does to read this page. Rather, it is generally an instantaneous, "obvious" decision for most managers. Herein lies the real problem. On what basis does the manager decide that the job involves a scientific or engineering technicality or that it requires "the ability to think"? That is, on what basis does the manager determine his manpower requirements. From the research, the author believes that this determination is based on a combination of the specific determinants listed in Chapter III together with managerial judgment and intuition. This constitutes the process of establishing manpower requirements that is presently used. But if there were some standard which could guide and improve the manager's decision process, there could be an improvement in the utilization of scientists and engineers resulting in a net dollar savings to the manager as well as a reduction in the shortage of scientists and engineers.

Development of a Standard

By relating the characteristics of a scientist or engineer to the

requirements of a job, the manager is able to determine the necessit of requesting scientific or engineering services. Since the actual or task is the primary focus here, the characteristics of a scientis engineer together with the manager's "past experience" may be though of as TASK RELATED DETERMINANTS.

Conversely, the other determinants listed in Chapter III--flexi bility, economics, availability, "red tape", politics, prestige, prejudice, and priority--are all independent of the actual task to b performed. These are considered to be NON-TASK RELATED DETERMINANTS

The task related determinants are directly dependent on the tas to be performed. If the task is to weld two pieces of steel, someon with this particular skill or knowledge must be employed. On the o r hand, the non-task related determinants have no relationship to the b. If the steel is to be welded on a high scaffold, a welder who is af d of heights will not be useful, but an adventurous young man who is available might be quickly taught the necessary fundamentals of wel g.

It is not suggested that the specific determinants mentioned i. Chapter III exhaust the list of those possible. But it is assumed t any other specific determinant can be logically placed in one of th two categories.

The manager must consider both the task related determinants a the non-task related determinants in his decision to require scient c and engineering services. If he is objectively aware of all the specific determinants that are significant to his particular situat , he is in a position to consider the legitimacy of each in the deter mination of his manpower requirements.

Herein lies the key to the development of a standard for deter ng

scientific and engineering manpower requirements: Each specific determinant must be carefully identified and considered as to its relevance and legitimacy. Once this is done, those that are considered legitimate are the only ones used to establish manpower requirements.

The second phase of the development of this standard is to decide the legitimacy of each determinant. If a manager's decision concerning manpower requirements is consistent with an established basis, it may be said that his decision is legitimate. But who establishes such a basis? It is the thesis of the author that this is the function of top management. The legitimacy of a particular determinant or of the application of a determinant in a particular situation is directly dependent on the overall objectives of the organization--whether it be an industrial firm or the U. S. Air Force. The overall objectives are established by the top management and every decision within the organization must be consistent with these objectives. This of course includes decisions as to which specific manpower skills are required. Often the first line manager making this decision does not have a clear understanding of the overall objectives of the organization and therefore is not in a position to make good manpower decisions. If top management feels that the first line manager should not or cannot have a clear understanding of the overall objectives, it should provide some very specific guidance as to which determinants are legitimate and which are not. But, if the first line manager is aware of the overall goals and is free to make decisions relative to them, then he can decide for himself which determinants are legitimate.

The standard proposed herein, therefore, consists of two points:

1. The first line manager should carefully and objectively identify all the specific determinants involved in a particular decision to establish requirements for scientific and engineering services.

2. He should then judge the legitimacy of each of these specific determinants on the basis of the organization's overall objectives and use only those determinants judged to be legitimate in his establishment of manpower requirements.

Mentally grouping determinants into the categories TASK RELATED and NON-TASK RELATED will aid the manager both in identifing all the determinants involved and in judging the legitimacy of each.

This standard is not a radically new idea. Rather, it challenges one to apply the depth, objectivity, and thoroughness it requires. Managers today are somewhat aware that a variety of determinants are involved and that some can be considered illegitimate. But the difficulty is that this is only a vague awareness. This aspect of management is still an art based on human intuition whereas it could approach the accuracy and repeatability of a science if a standard such as the one proposed were used.

A Practical Application of this Standard

Today, if two managers were to independently decide which skills were necessary to perform a particular task, they might arrive at two very different conclusions. For example, in the Foreign Technology Division (FTD) at Wright-Patterson Air Force Base, just this situation occurred. The Manpower Engineering Team confirmed the FTD manager's decision that engineers were needed in the Resources Application Office, but a member of an inspection team believed that this was an unnecessary application of engineering talent. The arguments for using engineers included the necessity for 1) technical communication,2) technical

interpretation of guidance from higher headquarters, 3) the general problem solving technique learned in engineering school, and 4) the assurance that the job would be performed well (i.e. a non-engineer may fail to perform the job well) (Ref 153). On the other hand the arguments against using engineers included 1) the majority of the workload is administrative - 60%, 2) the job will hurt the growth of young engineering officers, and 3) the officers are dissilusioned--they are not doing engineering work as they thought they would when they entered the Air Force (Ref Anonymous).

If the actual determinants for this task were identified, the two parties could take each one in turn and debate its legitimacy. But they presently do not have a common understanding and agreement as to which determinants are legitimate because of confusion as to the relationship of manpower requirements to the overall goals of the Air Force.

Let us apply the standard to this example to see how it can work in practice. It is first necessary to identify all the determinants involved in the decision. From the arguments given for and against the use of engineers we can see that some of the determinants are:

1. The ability to communicate (i.e., transmit and receive) technical ideas.
2. The "ability to think" related specifically to the problem solving technique learned in a college curriculum.
3. The peace of mind of the supervisor that the job would be performed well.
4. 60% of the workload is administrative.
5. Specific engineering experience is important to the careers of young engineering officers.
6. To make sure the Air Force retains its critical talent, it is important to give young officers the type of work they expected to perform when they entered the Air Force.

To aid in assuring that all determinants involved are mentioned, the determinants are categorized. Task related determinants would include those numbered 1, 2, and 4, while non-task related determinants would be 3, 5, and 6. Since we are not familiar with all the details of this particular situation, we cannot know whether other determinants are involved. But by imagining some of the details that would be likely, we can assume a few more determinants into this situation. First let us consider task related determinants. They might include:

7. Creativity to recognize new applications of established resources.

8. The necessity for an analytic ability to organize data into a logical and concise form.

9. The manager's past experience in identification of tasks to be accomplished.

10. The security of the nation is directly dependent, in some measure, on an accurate accomplishment of the job.

11. The necessity for accomplishing several small tasks, each requiring a different skill but not large enough to employ full time a person possessing each skill. Therefore one person who can perform all the tasks is needed.

12. Keeping the organizational boundaries distinct is more important than efficient utilization of engineers.

13. The recent budget cuts require that only one secretary be hired for every three that leave the Civil Service.

14. The manager of the Resources Application Office is an engineer himself and finds it easier to direct engineers to do work than people of other skills.

Now let us try to judge the legitimacy of each of these determinants. First it is necessary to establish the overall goals of the Air Force. Air Force Manual 1-1, United States Air Force Basic Doctrine, states that "Aerospace forces are designed to be employed...to influence enemy decision making in directions compaitble with our basic national

objective (Ref 1:1-1). It is also assumed that this should be done as economically as possible. Since we are not familiar with the precise function of the Resources Application Office, we must assume that the task related determinants given and assumed actually represent real requirements of the tasks to be performed. If they do, then they can be judged to be legitimate. But if, for example, there is no requirement to organize data into a logical and concise form, determinant number 8 should not even be listed. The manager must be willing to realize that a task actually does or does not require some particular skill or ability. This is an application of the objective identification of all the specific determinants. The fact that the manager wants an engineer and then "adjusts" the definition of the task to specify a skill which only an engineer possesses can not be judged legitimate under the author's understanding of best attainment of the overall Air Force objectives.

Now let us consider the legitimacy of the environmental determinants. First consider determinant number 3. Perhaps closer supervision of a non-engineer would assure that the job is performed well. If the cost of such closer supervision is less than the differential costs between an engineer and a non-engineer then determinant number 3 can be judged illegitimate. On the other hand, if the reverse is true, this determinant could be judged legitimate. The legitimacy of determinant 14 is judged on a similar basis.

The expression of determinants 5 and 6 represents cognizance of an Air Force goal to train and retain high quality engineering officers. If this goal is in reality emphasized by Air Force top management, why is it that management refuses to support engineers with secretaries

(determinant number 13)? In Chapter III it was emphasized that the job satisfaction, and consequently the retention, of engineers is somewhat dependent upon the amount of support they receive from secretaries and other support personnel. In the short run, some dollars can be saved by reducing the engineering support. Although this savings supports the goal of economy of operations, it conflicts with the desire to retain high quality engineering officers. It is the author's opinion that the first line manager should not be expected to judge the legitimacy of these determinants under these conditions; rather Air Force top management should resolve this conflict between goals and direct all sub-organizations to act consistently with this resolution.

Now consider determinants 11 and 12. As an example, assume that determinant 11 refers to a job that entails design, testing and publication of results concerning some technical phenomena. If an engineer were hired he could perform the design, set up the laboratory equipment to test his design, write the report, type the report and deliver it to the requesting authority. On the other hand, the requesting authority could cross organizational boundaries to ask an engineering organization to perform the design, a laboratory organization to test it, and an administrative organization to type and deliver the final report. This would require that several specialists work under the supervision of the requesting authority for a short time. To the author, the overall goals of the Air Force would not be compromised by this type of action; therefore, determinants 11 and 12 are judged to be illegitimate.

In summary there are four categories of determinants. We have judged that determinants 1, 2, 4, 7, 8, 9, and 10 are legitimate; that

determinants 11 and 12 are illegitimate; that the legitimacy of determinants 5, 6, and 13 must be decided at higher management levels; and that the legitimacy of determinants 3 and 14 depends on relative cost comparisons. In practice the last category could be rather easily decided, but the third category is presently a definite stumbling block in the accurate determination of manpower requirements.

If we consider only those determinants judged definitely legitimate, we see that those numbered 1, 2, 7, 8, and 10 point to the requirement of an engineer while determinant 4 suggests an administrative assistant. Now with this "scientific" analysis, the manager can use his "past experience" (determinant 9) and judgment to fine tune the decision into one he can rationally and objectively justify.

Use of this Standard

This type of standard is, of course, not the easiest to use and put into practice. It first requires a detailed analysis and understanding of the job to be done. It then requires an objective appraisal of all the possible determinants that may affect the decision. These are perhaps the most difficult steps, for they require the manager not only to think deeply but to disregard his many personal biases and prejudices.

Once the first line manager has listed all the determinants, has weighed the importance of each one, and has made a decision he can rationally justify, he has done about all he can. It is the task of higher level management to support this legitimate justification.

If, for example, the real reason a manager requested an engineer is that he honestly believed that a qualified technician is not available,

this justification should be openly established. Then if the manager and his supervisor differ as to the necessity of an engineer, the real issue can be discussed, rather than arguing about one of the "accepted" justifications--complexity of the job, for example. Perhaps the supervisor knows of an available technician.

The importance of the role of all management levels must be understood. Since the first line manager is expected to reflect the wishes and desires of higher management, it is vitally important that top management "wish and desire" improvement. It is the responsibility of top management to understand the full significance of this standard and to project genuine and sincere interest in its implementation downward in a forceful manner.

The role of top management in the improvement of utilization of scientists and engineers has been recognized by many authorities. Walters in his book Research Management stated:

> ...the improved utilization of scientific talent will require more efficient management of science and scientists (Ref 116:1).

And John R. Moore, vice-president of North American Aviation challenged the National Advanced Technology Management Conference in 1962 with:

> We need real breakthroughs in the state of the art of management which will...release creative personnel for creative work and conserve the consecutive time available for our best people to work in areas of their greatest competence (Ref 47:19).

A conference in 1953 sponsored by the National Manpower Council concluded

> Important gains in manpower utilization can take place only if current practices are under constant critical review and that little happens in an organization unless management actively seeks it. It is not enough for top management to be receptive; it must also be willing to exert pressure on the whole organization

of technical and scientific manpower. (Ref 67:93).

Judgment of Overstatement of Requirements

In Chapter I it was conjectured that the requirements for scientific and engineering services are overstated. The first hypothesis that a standard does exist was not accpeted. Without a standard by which one could judge the correct statement of requirements, it is highly unlikely that the present statement is accurate. It has also been shown that it is advantageous to the manager to have too many scientists and engineers rather than too few. It is, therefore, highly unlikely that the requirements are understated. It can therefore be judged that the requirements for scientific and engineering services are in fact overstated. It may be appreciated that the scope of the research did not allow a determination of the magnitude of this overstatement or any investigation as to exactly which organizations might have overstated their requirements.

V. Summary, Conclusions, and Recommendations

Summary

Since the early 1950's there has been national concern over the shortage of scientists and engineers. Since the real shortage is of scientific and engineering services, the solution to improve the utilization of the available scientists and engineers is obvious. By increasing the job satisfaction of these people, not only is their efficiency increased, but others will realize that the profession offe fine advantages and may desire to join it. One way to enhance the sati faction from their employment is to provide them technical and clerica support. To do this efficiently suggests a management that can objectively analyze a task and group its subtasks in such a manner that eac employee has an interesting and challenging job and is utilized in an efficient and effective manner. By doing this, the employee not only produces efficiently, but he also grows and learns to accept even high challenges.

Since this responsibility of management is so vital and important it was hypothesized that there might exist some standard or guideline to assist the manager. A search for such a standard was conducted in the literature, industrial firms, professional societies, federal government agencies, and the Air Force. Although no standard was fou the information gathered provided the basis of a description of how this responsibility to define manpower requirements is actually fulfil ed.

The description of this proceedure in Chapter III revealed that the establishment of requirements for scientists and engineers is

presently more of a managerial art than a science. That is, managers depend to a large extent on their own personal judgment and intuition and have few, if any, concrete methods or proceedures which could be considered scientifically repeatable or accurate. The research did reveal that there are a number of specific factors, referred to as determinants, that play an important role in establishing manpower requirements. But, in general, managers are only vaguely aware of such determinants and do not know how to use them in any definite, straightforward, objective manner.

In the analysis in Chapter IV these specific determinants are grouped together into two categories. TASK RELATED DETERMINANTS are those that are related directly to the requirements of the task while NON-TASK RELATED DETERMINANTS have no relationship to the task to be performed. The specific task related determinants found during the research were technical expertise, creativity, analytic ability, ability to communicate technical ideas, and that quality of a college graduate known as the "ability to think". The specific non-task related determinants found were the flexibility of the scientist-engineer to perform technician's and administrative tasks as well as scientific-engineering tasks; the availability or non-availability of a specific skill or person; economics and budgetary considerations; administrative problems involved in getting requests for manpower authorizations approved; politics on a local organizational level; prestige of the manager; prejudice of a manager for scientists or engineers; and the priority of the particular program. The manager's "past experience" was listed as a task related determinant but actually serves to tie all the determinants together into a final decision.

Since the hypothesis that there is a standard or guideline which aids managers in determining requirements for scientific and engineering services was not accepted, a standard was proposed by the author. The purpose of this standard was to provide a method of making the determination of technical manpower requirements more exact. It requires the first line manager to carefully and objectively identify all the specific determinants involved in a particular decision to require manpower skills. Then it asks him to judge the legitimacy of each of these determinants and to use only those judged to be legitimate in the decision process. Legitimacy of a particular determinant or the application of a determinant in a particular situation was shown to be directly dependent upon the overall objectives of the organization. It is therefore necessary that top management give the first line manager some specific guidance so that he can decide the legitimacy of a determinant on the basis of the overall objectives.

The usefulness of making this decision process into a repeatable science was emphasized with an example. Two managers using the present method of establishing technical manpower requirements arrived at completely opposite decisions because they each used independent arguments. In effect, each was considering a different set of determinants, neither set being complete. If they had first agreed upon all the determinants involved in the decision, they would have had a common understanding on which to base their arguments. But even with an agreement as to which determinants were involved, they would not have been able to agree on the legitimacy of all of them because the relationship of manpower requirements to the overall goals of the Air Force has not been made clear.

At the beginning of the research effort it was conjectured that the requirements for scientific and engineering services may be overstated. It was suggested that to judge this overstatement a standard was needed, but since no standard is presently used there is no way to judge if the present statement of requirements is accurate. Since it is more advantageous to have too many rather than too few scientists or engineers, it was assumed that the requirements are in fact overstated.

Conclusions

The description of the proceedure for determining operational requirements for scientific and engineering services revealed that a number of specific determinants are actually used by managers. From the fact that not one individual, either in the literature, in replies to letters, or in interviews was able to express a detailed comprehension of these determinants, it is concluded that no one is explicitly aware of them and their significance. Some individuals did reveal an obscure cognizance of a few of the determinants and were aware that some were acceptable while others were not.

The present process of determining manpower requirements is based somewhat on these specific determinants, but is more dependent on subjective factors such as the manager's judgment, and intuition. This provokes a tremendous difficulty in communication. If the manager can not explicitly express his reasons for making a particular decision, how can he possibly expect to communicate his ideas accurately to someone else? Moreover, how can he be sure that he knows what his own ideas are? It is commonly assumed that if a person cannot express an idea

verbally, he may not really understand the idea himself. This situation could be alleviated by a clear and accurate identification of all the determinants involved in a decision for manpower requirements. These determinants can be categorized into TASK RELATED DETERMINANTS and NON-TASK RELATED DETERMINANTS. Categorizing the determinants can assist the manager in his conception of the importance, relevance, and legitimacy of the specific determinants as well as aid him in identifying all the pertinent determinants.

The manager that has realized that his justifications are based on some sort of determinants may be confused both as to the exact definition of these determinants and as to their legitimacy. Managers have not been required to explicitly define their determinants and additionally, they have very little on which to base a decision as to the legitimacy of the determinants they can identify. From the research, the author has concluded that these are the two basic problems concerning determinations of manpower requirements for scientists and engineers.

Recommendations

In order to solve these two basic problems, considerable effort is needed from all management levels. The first line managers must be taught the significance of manpower determinants and must learn to recognize specific ones. They then must have some basis for judging the legitimacy of these determinants. Providing and communicating this basis to the first line managers is the responsibility of top management. Top management must agree on what the overall organizational goals and objectives are, then on this basis it could make a list of

legitimate and illegitimate determinants, or it could communicate the goals and objectives to the first line managers in such a manner that they could decide for themselves which determinants are legitimate and which are illegitimate. It is then vitally necessary that the whole organization deal consistently with the decision as to which determinants are legitimate. That is, the authority which approves or disapproves manpower authorizations should not use a different set of legitimate determinants than the first line manager uses.

For any of these recommendations to be adopted, top management must be convinced that improved utilization is important and that a feasible solution is within the framework represented herein. Then it must assure that its conviction is effectively communicated down through all levels of management. Only with the sincere and genuine support of top management can there be any hope of improvement in the utilization of scientists and engineers.

Since no research effort is really ever complete, it is appropriate to suggest further areas of research. Before this standard can be applied on a wide scale it would be best to test and use it in a pilot study. This may involve explaining the standard to a variety of people and using their reactions, criticisms, and suggestions to determine methods of application on a wider scale. Perhaps a rather autonomous organization could be found that would be willing to test the standard. During the research, the author found that the Department of Defense Laboratories (Ref 152), specifically the Air Force Avionics Laboratory (Ref 161), seemed especially interested in improving the utilization of their technical manpower.

Research is needed to determine practical and effective methods of

teaching first line managers how to recognize and employ specific manpower determinants. Also, practical methods are needed for convincing top management that it should be sincerely and genuinely interested in improved manpower utilization and should effectively communicate this interest throughout the organization.

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135. Martin, Erle. Vice Chairman, United Aircraft, East Hartford, Conn. 06108. June 20, 1969.

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161. Nordlund, R.J. Chief Scientist, Air Force Avionics Laboratory, Air Force Systems Command, Wright-Patterson AFB, O. July 22, 1969.

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165. Walters, Wilmer C. Jr., Lt Col, USAF. Assistant Deputy for Project Management, Deputy for Reconnaissance and Electronic Warfare, Aeronautical Systems Division, Air Force Systems Command, Wright-Patterson AFB, O. July 15, 1969.

166. Wilson, Charles C. Chief, Analysis Branch, Electronic Intelligence Division, Engineering Directorate, Foreign Technology Division, Air Force Systems Command, Wright-Patterson AFB, O. August 5, 1969.

167. Zabetakis, Stanley G. Chief, Data Processing Branch, Engineering Data Division, Engineering Directorate, Foreign Technology Division, Air Force Systems Command, Wright-Patterson AFB, O. July 8, 1969.

Appendix A

Copy of Letter Requesting Information

The next page displays a copy of the letter sent to industrial firms and not-for-profit firms. In the letter sent to professional societies and governmental agencies, the last paragraph was modified slightly to appropriately reflect the differences between these types of organizations.

DEPARTMENT OF THE AIR FORCE
Air Force Institute of Technology
Wright-Patterson Air Force Base, Ohio 45433
AFITSE-S

13 June 1969

Mr. R.I. McKenzie, President
Aerojet-General Corp.
9100 E. Flair Dr.
El Monte, Cal. 91731

Dear Sir:

In support of the thesis requirement for a Master's Degree in Systems Management at the Air Force Institute of Technology, I am researching the following topic: "An Evaluation of the Manpower Allocation System for Scientists and Engineers in the Air Force Systems Command". Preliminary studies have indicated that research and development personnel feel that their abilities are not fully utilized. I am approaching this problem by examining the method now used by the Air Force Systems Command to generate job descriptions for its professional personnel.

The scope of this study focuses on the development of manning requirements, rather than the personnel staffing function. Therefore, I am interested only in the methods and standards used to evaluate the work that each individual is to perform. I am concentrating on five specific professions: chemist, physicist, electronic engineer, mechanical engineer, and astronautical/aeronautical engineer. This limitation is necessary due to a September suspense date for the completed thesis and is justified because an adequate cross section of research and development fields is represented.

To achieve a broad understanding of current practices in the determination of professional skills necessary to meet the objectives of a research and development effort, your assistance in this research effort is requested.

I am interested in learning what guidance, criteria, and standards are used by the individuals who determine your manpower requirements for the five professions listed above. I would appreciate your forwarding this request to those who perform this function in your organization.

Thank you for your assistance in this endeavor.

Respectively,

William A. Brummer

WILLIAM A. BRUMMER
1st Lt. USAF

Appendix B

List of Recipients of Letters (with Date of Letter)

Asterisk indicates that a reply was received from recipient.

Industrial Firms

Aerojet-General Corp.
El Monte, Cal.
13 June 1969

Air Reduction Co., Inc.
New York, N.Y.
16 June 1969

Allis-Chalmers Manufacturing Co.
Milwaukee, Wis.
16 June 1969

Ampex Corp.
Redwood City, Cal.
13 June 1969

Avco Corp.
New York, N.Y.
13 July 1969

*Babcock and Wilcox Co.
New York, N.Y.
14 July 1969

Jerome Barnum Associates
Scarsdale, N.Y.
20 June 1969

Barry-Wright Corp.
Watertown, Mass.
16 June 1969

Bell Aerospace Corp.
Buffalo, N.Y.
13 June 1969

*The Bendix Corp.
Detroit, Mich.
13 June 1969

*The Boeing Co.
Seattle, Wash.
13 June 1969

*Burroughs Corp.
Detroit, Mich.
16 June 1969

*Chrysler Corp.
Detroit Mich.
16 June 1969

Collins Radio Co.
Dallas, Tex.
16 June 1969

Combustion Engineering, Inc.
New York, N.Y.
16 June 1969

Comprehensive Deisgners
Philadelphia, Pa.
8 July 1969

Control Data Corp.
Minneapolis, Minn.
13 June 1969

*Curtiss-Wright Corp.
Wood-Ridge, N.J.
16 June 1969

Cutler-Hammer, Inc.
Milwaukee, Wis.
16 June 1969

Dow Chemical Co.
Midland, Mich.
16 June 1969

E.I. duPont de Nemours & Co.
Wilmington, Del.
16 June 1969

*Fairchild Hiller Corp.
Germantown, Md.
16 June 1969

*The Firestone Tire & Rubber Co.
Akron, O.
16 June 1969

Ford Motor Co.
Dearborn, Mich.
13 June 1969

The Garrett Corp.
Los Angeles, Cal.
13 June 1969

*General Dynamics Corp.
New York, N.Y.
13 June 1969

*General Electric Co.
New York, N.Y.
13 June 1969

General Precision Controls, Inc.
New York, N.Y.
13 June 1969

The B.F. Goodrich Co.
Akron, O.
13 June 1969

*Goodyear Tire & Rubber Co.
Akron, O.
13 June 1969

Grumman Aircraft Engineering Corp.
Bethpage, N.Y.
16 June 1969

*Hazleton Laboratories, Inc.
Falls Church, Va.
16 June 1969

*Hewlett-Packard Co.
Palo Alto, Cal.
16 June 1969

Honeywell, Inc.
Minneapolis, Minn.
13 June 1969

Hughes Aircraft Co.
Culver City, Cal.
13 June 1969

*International Telephone & Telegraph Corp.
New York, N.Y.
13 June 1969

Lear Siegler, Inc.
Santa Monica, Cal.
13 June 1969

*Ling-Temco-Vaught, Inc.
Dallas, Tex.
13 June 1969

Arthur D. Little, Inc.
Cambridge, Mass.
16 June 1969

Litton Industries, Inc.
Beverly Hills, Cal.
13 June 1969

*Lockheed Aircraft Corp.
Burbank, Cal.
13 June 1969

*Martin-Marietta Corp.
New York, N.Y.
13 June 1969

*McDonnell Douglas Corp.
St. Louis, Mo.
13 June 1969

*Monsanto Co.
St. Louis, Mo.
16 June 1969

The National Cash Register Co.
Dayton, O.
16 June 1969

North American Rockwell Corp.
El Segundo, Cal.
13 June 1969

*Northrop Corp.
Beverly Hills, Cal.
16 June 1969

Owens-Corning Fiberglass Corp.
Toledo, O.
16 June 1969

Philco-Ford Corp.
Philadelphia, Pa.
16 June 1969

Pratt & Whitney, Inc.
West Hartford, Conn.
16 June 1969

*Radio Corporation of America
New York, N.Y.
13 June 1969

Republic Aviation Corp.
Farmingdale, L.I., N.Y.
14 July 1969

Sanders Associates, Inc.
Nashua, N.H.
16 June 1969

*Sherwin-Williams Co.
Cleveland, O.
16 June 1969

Singer Co.
New York, N.Y.
16 June 1969

Space Craft, Inc.
Huntsville, Ala.
16 June 1969

Sperry Rand Corp.
New York, N.Y.
13 June 1969

Technology, Inc.
Dayton, O.
16 June 1969

Tektronix, Inc.
Beaverton, Ore.
13 June 1969

Teledyne, Inc.
Los Angeles, Cal.
13 June 1969

Texas Instruments, Inc.
Dallas, Tex.
13 June 1969

Thiokol Chemical Corp.
Bristol, Pa.
16 June 1969

*TRW, Inc.
Cleveland, O.
14 July 1969

*Union Carbide Corp.
New York, N.Y.
16 June 1969

*United Aircraft Corp.
East Hartford, Conn.
13 June 1969

Western Electric Co., Inc.
New York, N.Y.
13 June 1969

*Westinghouse Electric Corp.
Pittsburg, Pa.
16 June 1969

<u>Not-For-Profit Firms</u>

*Battelle Memorial Institute
Columbus, O.
16 June 1969

Jet Propulsion Laboratories
Pasadena, Cal.
16 June 1969

*The MITRE Corp.
Bedford, Mass.
16 June 1969

*The Rand Corp.
Santa Monica, Cal.
16 June 1969

Professional Societies

*American Chemical Society
Washington, D.C.
16 June 1969

*American Institute of Aeronautics and Astronautics
New York, N.Y.
13 June 1969

*American Institute of Industrial Engineers
New York, N.Y.
4 August 1969

American Institute of Management
New York, N.Y.
8 July 1969

*American Institute of Physics
New York, N.Y.
16 June 1969

*American Management Association Inc.
New York, N.Y.
8 July 1969

*American Society of Mechanical Engineers
New York, N.Y.
13 June 1969

*Engineers Joint Council, Engineering Manpower Commission
New York, N.Y.
13 June 1969

Industrial Research Institute
New York, N.Y.
4 August 1969

*Institute of Electrical and Electronics Engineers, Inc.
New York, N.Y.
13 June 1969

*National Academy of Sciences
Washington, D.C.
8 July 1969

National Manpower Council
Columbia University
New York, N.Y.
10 July 1969

*National Science Foundation
Washington, D.C.
8 July 1969

**National Security Industrial Association
Washington, D.C.
8 July 1969

*National Society of Professional Engineers
Washington, D.C.
8 July 1969

*Scientific Manpower Commission
Washington, D.C.
13 June 1969

**This letter was returned by the Post Office and marked "moved, not forwardable".

Federal Governmental Agencies

*Library of Congress, National Referral Center for Science and Technology
Washington, D.C.
17 July 1969

*National Aeronautics and Space Administration, Associate Administrator for Organization and Management
Washington, D.C.
20 June 1969

*National Manpower Policy Task Force
Washington, D.C.
1 August 1969

*U.S. Army Manpower Management Agency (AMXMM)
Arlington, Va.
20 June 1969

*U.S. Department of Labor, Bureau of Labor Statistics, Division of Man-Power and Occupational Outlook
Washington, D.C.
8 August 1969

U. S. Navy Manpower Validation Support
Washington, D.C.
20 June 1969

Appendix C

Statistical Summary of Number of Letters Sent and Replies Received

Group	No. of letters sent	No. of replies	% replies
Industry	67	26	39
Not-for-profit	4	3	75
Professional societies	16	12	75
Governmental agencies	6	5	83
Total	93	46	50

Vita

William A. Brummer was born on 11 August 1944 in Salinas, California, the son of Louis W. and Ruth P. Brummer. He attended three years of high school in Ridgewood, New Jersey, and then graduated from Wade Hampton High School in Greenville, South Carolina in 1962. He returned to New Jersey to attend Stevens Institute of Technology in Hoboken. In 1966 he graduated with the degree of Mechanical Engineer and was commissioned a Second Lieutenant in the United States Air Force. His first assignment was to the Air Force Missile Development Center, Holloman Air Force Base, New Mexico. There he was a project officer testing inertial guidance systems on the high speed test track for the Central Inertial Guidance Test Facility. In 1968 he began studies in the Department of Systems Management, Air Force Institute of Technology.

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13. ABSTRACT This thesis describes and analyzes the present procedure used by managers to establish operational manpower requirements for scientists and engineers. Data were gathered from the literature; from 46 industrial firms, professional societies, and governmental agencies; and from over 50 persons interviewed by the author. It was found that there is no definite, explicit method of deciding that a scientist or engineer is needed to perform a particular task. Rather, this function of management is greatly dependent on the individual manager's judgment and intuition. When the present procedure was analyzed, it was found that there are some specific determinants which are used to establish these requirements, but that managers are only vaguely aware of their significance. To improve this procedure of establishing requirements for scientists and engineers, it is proposed to first teach managers to carefully and objectively identify <u>all</u> the specific determinants involved in a particular situation. Then they should judge the legitimacy of each specific determinant on the basis of the organization's overall objectives and use only those determinants judged to be legitimate in the establishment of manpower requirements. The recommendations emphasize that top management must be sincerely interested in this type of improvement and assure that all management levels are working consistently toward this goal.

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Scientist and engineers						
Personnel management						
Manpower validation						
Work time standards						
Job analysis						